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A Theory of Future's Market Responses to Government Crop Forecasts

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A Theory of Future's Market Responses to Government Crop Forecasts

Abstract

Recently, there has been considerable debate in the government, business and academic communities regarding the value, accuracy, frequency and necessity of government crop forecasts. This debate has intensified due to several developments. The first is the recent trend toward slowing the growth in non-defense public sector expenditures. As the federal budget has been stretched tighter, some information activities have been curtailed. These cutbacks have coincided with a second, not necessarily uncorrelated, development; the increased sophistication of private information collection activities. Private firms now partially duplicate government efforts to disseminate information on, and predictions of, crop forecasts.

Disciplines

Business Law, Public Responsibility, and Ethics | Economic History | Economic Theory

A Theory of Future's Market Responses
to Government Crop Forecasts

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I. Introduction

Recently, there has been considerable debate in the government, business and academic communities regarding the value, accuracy, frequency and necessity of government crop forecasts. This debate has intensified due to several developments. The first is the recent trend toward slowing the growth in non-defense public sector expenditures. As the federal budget has been stretched tighter, some information activities have been curtailed. These cutbacks have coincided with a second, not necessarily uncorrelated, development; the increased sophistication of private information collection activities. Private firms now partially duplicate government efforts to disseminate information on, and predictions of, crop forecasts. Just and Rausser (1981) have shown that these private forecasts can match and, in many cases, even dominate the government's forecasts. Several recent incidents in which errors in government forecasts have had perverse effects on market prices have also had a bearing on the debate.^{1/}

The discussion involves several interesting questions. Does the existence of private information agencies reduce or negate the value of public information? Should the government continue to collect information that private agencies collect? Should the government concentrate its efforts on large or small markets? Should it release its information more or less frequently, or earlier or later in the crop year? How should the market properly respond to announcements that are known to be error-prone? How can we determine if announcements are worthwhile? All these questions have been discussed in various forums. However, this discussion has been hampered by the lack of a general theoretical framework. This paper introduces such a framework which is then utilized to derive answers to

these and other related questions. Our analysis differs from earlier studies in that it explicitly allows for the market to collect and process information that is unavailable to the government information agency.

Our discussion is organized along the following outline. In the next section we model a futures market equilibrium and show how that equilibrium reflects information provided by the government sector. Section III contains a discussion of how the model might be extended to analyze the social welfare derived from government announcements. We discuss several concrete implications of the theory in Sections IV and V. The discussion in Section IV is focussed on questions which pertain to the optimal strategy for the collection and dissemination of information by the government while Section V considers issues that arise in empirically measuring the impacts of government announcements. Our main conclusions are summarized in Section VI.

II. Market Equilibrium

In this section, we establish a model of future's price determination in a market with an uncertain future supply of a representative commodity. We utilize this model to illustrate how government supply forecasts affect market price, given that the market utilizes government information optimally. To begin we assume that the true supply becomes known to the market on day H (harvest day) where H is known with certainty. The true supply is denoted as S_H . In any period $t \leq H$, individuals can purchase or sell claims to part of the expected harvest through a futures market that clears daily. Let D_t denote the total amount of the future harvest claimed through day t where $t \leq H$. We assume that the stock demand at t has the simple linear form

$$D_t = \gamma - P_t + u_t ; \quad t = 0, 1, \dots, H \quad (1)$$

where γ and β are positive parameters that are independent of t , P_t denotes the futures market price at t for delivery at H and u_t is a daily demand shock which has a mean of zero and variance of σ_u^2 .

On day H this market will clear with $S_H = D_H$ and the price will be P_H . For $t < H$, S_H is a random variable and we assume that the market clears on days prior to H such that $D_t = \hat{S}_t^M$ where \hat{S}_t^M is the market participants' expectation of S_H conditioned on information available to them through day t .

The arrival of information on the value of S_H from some arbitrarily chosen day 0 through day H can be summarized by a sequence of random variables $\{\epsilon_1^M, \dots, \epsilon_{H-1}^M, \epsilon_H^M\}$, where we define ϵ_t^M as the market's forecast revision on day t according to

$$\epsilon_t^M = \hat{S}_t^M - \hat{S}_{t-1}^M \quad t = 1, \dots, H. \quad (2)$$

Assuming that market participants use information efficiently it follows that $E(\epsilon_i^M) = 0$ and, if $i \neq j$, $E(\epsilon_i^M \epsilon_j^M) = 0$. Let $\sigma_{M,i}^2$ denote the variance of ϵ_i^M . It follows that

$$\hat{S}_t^M = S_H - \sum_{i=t+1}^H \epsilon_i^M. \quad (3)$$

That is, the current forecast error ($S_H - \hat{S}_t^M$) can be expressed as the sum of subsequent forecast revisions. Since we are assuming that markets use information efficiently, these subsequent revisions depend only upon information not yet revealed to the market. In the remainder of the paper we will frequently refer to the ϵ_i^M 's simply as "new information provided to the market." Notice that the market's forecast error variance, V_t^M , falls monotonically as t approaches H since $V_t^M = \sum_{i=t+1}^H \sigma_{M,i}^2$.

Having already stated that $D_t = \hat{S}_t^M$ is the market-clearing condition on day t , it follows from (1) and (3) that the market-clearing price for day t must be

$$P_t = \frac{1}{\beta}(\gamma - S_H + \sum_{i=t+1}^H \epsilon_i^M) + \frac{1}{\beta}u_t. \quad (4)$$

Thus the price in every period t is a function of market forecast errors and the true supply. It follows from (4) that $P_{t+1} - P_t = -\frac{1}{\beta}\epsilon_{t+1}^M + \frac{1}{\beta}(u_{t+1} - u_t)$.

In other words, daily changes in the futures price result entirely from new information in the marketplace.

The Effect of Government Predictions on the Current Equilibrium Price

We can now introduce the government into the market. The government is assumed not to be an active trader in the market we are analyzing. However,

it does collect information about S_H . The government announces this information to the market either directly or through forecasts of S_H based on this information. For the time being, we assume that the government conveys information entirely through its forecasts of S_H . We are concerned with how these forecasts influence the equilibrium path of prices, P_t . Our previous discussion has already given us a large part of the answer. To the extent that government announcements affect the equilibrium price path it must only be through the new information conveyed to the market, i.e., the unanticipated component of the announcement.

Like the private sector, the government receives new information about S_H from day 0 through day H. The arrival of this information to the government can be viewed as a sequence of independently distributed random variables $\{\epsilon_0^G, \epsilon_1^G, \dots, \epsilon_{H-1}^G, \epsilon_H^G\}$, where $E(\epsilon_i^G) = 0$, $\text{Var}(\epsilon_i^G)^2 = \sigma_{G,i}^2$, and $E(\epsilon_i^G \epsilon_j^G) = 0$ for $i \neq j$. Over a given time interval $[0, H]$ it is unlikely that the sets $\{\epsilon_0^M, \dots, \epsilon_H^M\}$ and $\{\epsilon_0^G, \dots, \epsilon_H^G\}$ will be equal if we assume that the private sector and public sector draw their ϵ 's from partially non-overlapping sources.^{3/} Even if the government revealed its ϵ 's as they were being drawn, unless the government could somehow deduce the ϵ^M 's as they too were being drawn, the two sets will generally be unequal.^{4/} Notice that our constructions imply that the true value of S_H is revealed to both the government and the market by the end of day H.

As we noted earlier, we assume that, periodically, the government issues forecasts of S_H based upon some of the ϵ^G 's it has drawn. As we showed in the preceding section, these forecasts will elicit a market

response only if they add to what the market already has learned about the value of S_H . In particular, let \hat{S}_{t+1}^G be an announced government forecast of S_H made on day $t+1$ that efficiently reflects all of the relevant information available to the government by that day, i.e.,

$$\hat{S}_{t+1}^G = S_H - \sum_{i=t+2}^H \epsilon_i^G. \quad (5)$$

Notice that \hat{S}_{t+1}^G will only cause a price movement if it differs from the market's existing forecast of S_H . According to (3) and (5), a necessary and sufficient condition for $\hat{S}_{t+1}^M \neq \hat{S}_{t+1}^G$ is that $\sum_{i=t+2}^H (\epsilon_i^M - \epsilon_i^G) \neq 0$.

To pursue this argument, consider how the market revises its prediction of S_H following a government announcement in period $t+1$, \hat{S}_{t+1}^G . Assuming that the market will weight its original prediction and the government's prediction in a way that will minimize the forecast error variance of the revised market prediction, \hat{S}_{t+1}^M , that new prediction can be written

$$\hat{S}_{t+1}^M = (1-\alpha)\hat{S}_{t+1}^M + \alpha\hat{S}_{t+1}^G = S_H - \sum_{i=t+2}^H \epsilon_i^M + \alpha \sum_{i=t+2}^H (\epsilon_i^M - \epsilon_i^G) \quad (6)$$

for some value of the real number α such that $0 \leq \alpha \leq 1$. If the market is rational (i.e., minimizing its forecast error variance), then the new forecast error variance, $\hat{V}_{t+1}^M = \text{Var}(\hat{S}_{t+1}^M - S_H)$, must be less than or equal to \hat{V}_{t+1}^M and they will only be equal if $\alpha = 0$ (i.e., the market ignores \hat{S}_{t+1}^G).

The formula for \hat{V}_{t+1}^M , for a given α , can be written

$$\hat{V}_{t+1}^M = (\alpha-1)^2 \sum_{i=t+2}^H \sigma_{M,i}^2 + \alpha^2 \sum_{i=t+2}^H \sigma_{G,i}^2 \quad (7)$$

where, for expositional ease, we are assuming that the covariance of ϵ_i^M and ϵ_i^G is equal to zero.^{5/} Differentiating \hat{V}_{t+1}^M with respect to α yields the first order condition for the market's optimal choice of α ,

$$\alpha = \left(\sum_{t+2}^H \sigma_{M,i}^2 \right) / \left(\sum_{t+2}^H (\sigma_{M,i}^2 + \sigma_{G,i}^2) \right). \quad (8)$$

The market will increase its weight on government forecasts, the larger is the market forecast variance relative to the sum of market and government forecast variances. The intuition underlying this result is that as market information tends to be noisier than government information, the market is more likely to discount its own forecasts when they differ from the government's forecasts. Notice that α will be set to zero (meaning that the

market places no value on government information) only if $\sum_{t+2}^H \sigma_{M,i}^2 = 0$ or if

$\sum_{t+2}^H \sigma_{G,i}^2 \rightarrow \infty$. The first case amounts to saying that the market has determined

S_H with certainty prior to the government's announcement. The second case implies that government announcements are so noisy that no useful information can be extracted from them. For all intermediate cases, government announcements will serve to lower market forecast error. Even if

$\sigma_{G,i}^2 > \sigma_{M,i}^2$, so that government forecasts tend to be noisier than market forecasts, the market will still in general assign a positive weight to government forecasts, i.e., $\alpha > 0$.

Given the market's revised forecast of S_H in response to the government prediction, the market's price on the day of the announcement, \tilde{P}_{t+1} , will be, according to (4), a function of the market's revised harvest forecast.

Specifically,

$$\tilde{P}_{t+1} = \frac{1}{\beta} \left(\gamma - S_H + \sum_{i=t+2}^H \epsilon_i^M - \alpha \sum_{i=t+2}^H (\epsilon_i^M - \epsilon_i^G) \right) + \frac{1}{\beta} u_{t+1}, \quad (9)$$

which shows that the market price level on day $t+1$ will be a function of the

market's anticipated government announcement ($\hat{S}_{t+1}^M = S_H - \sum_{i=t+2}^H \epsilon_i^M$) and the

unanticipated portion of the announcement ($\hat{S}_{t+1}^G - \hat{S}_{t+1}^M = \sum_{i=t+2}^H (\epsilon_i^M - \epsilon_i^G)$).

Price changes, however, will be entirely due to the unanticipated component of the government announcement and other new information obtained that day.

This can be seen directly by subtracting (4) from (9) to obtain

$$\tilde{P}_{t+1} - P_t = -\frac{1}{\beta} (\epsilon_{t+1}^M + \alpha \sum_{i=t+2}^H (\epsilon_i^M - \epsilon_i^G)) + \frac{1}{\beta} (u_{t+1} - u_t). \quad (10)$$

III. Evaluating the Social Returns to Government Prediction

To this point, we have shown how government forecasts are translated into price movements as the market extracts from these forecasts what it perceives to be new information about the upcoming harvest's size. We now suggest how our model can be extended to quantify the social value or "usefulness" of government announcements. In our framework, a government announcement at $t+1$ will be assumed to improve market efficiency and, thus, be socially valuable, if this announcement moves the market closer to the equilibrium price that would prevail if S_H were known with certainty.

Let $P_{H,t+1}$ denote the equilibrium price at $t+1$ if S_H were known with certainty, i.e., the supply-side certainty price. If the only uncertainty in the market comes from the demand side, then $\hat{S}_{t+1}^M = S_H$ and (4) implies that the price on day $t+1$ would be

$$P_{H,t+1} = \frac{1}{\beta}(\gamma - S_H) + \frac{1}{\beta} u_{t+1}. \quad (11)$$

In the absence of a government announcement, the deviation between $P_{H,t+1}$ and the actual price P_{t+1} will be, according to (4) and (11),

$$P_{H,t+1} - P_{t+1} = -\frac{1}{\beta} \sum_{i=t+2}^H \epsilon_i^M. \quad (12)$$

The lower the variance of $P_{H,t+1} - P_{t+1}$, the lower are the efficiency losses due to suboptimal inventory or production decisions resulting from market prices that do not reflect true supply conditions. The price variance implied by (12) is

$$V_{t+1}^P = E[(P_{H,t+1} - P_{t+1})^2] = \frac{1}{\beta^2} V_{t+1}^M. \quad (13)$$

With government announcements, $P_{H,t+1}$ will be unaffected but P_{t+1} is given by \tilde{P}_{t+1} , according to (9), and so the deviation of actual price from the "supply-side certainty" price will be

$$P_{H,t+1} - \tilde{P}_{t+1} = -\frac{1}{\beta} \left(\sum_{i=t+2}^H \epsilon_i^M - \alpha \sum_{i=t+2}^H (\epsilon_i^M - \epsilon_i^G) \right). \quad (14)$$

The corresponding price variance around $P_{H,t+1}$ is given by

$$\tilde{V}_{t+1}^P = E[(P_{H,t+1} - \tilde{P}_{t+1})^2] = \frac{1}{\beta^2} \tilde{V}_{t+1}^M. \quad (15)$$

We have shown earlier that since rational agents will only use government announcements to reduce their harvest forecast error variances, it must be that $\tilde{V}_{t+1}^M \leq V_{t+1}^M$. It then follows from (13) and (15) that $\tilde{V}_{t+1}^P \leq V_{t+1}^P$, with equality holding if, and only if, $\alpha = 0$. In other words, the average dispersion of actual price about the supply-side certainty price cannot be increased by erroneous government forecasts or estimates of its size regardless of how bad these forecasts tend to be. So long as these fore-

casts tend to convey any new and useful information, they will reduce this price variance.^{6/}

Comparing \tilde{V}_{t+1}^P to V_{t+1}^P gives us some leverage in evaluating the value of government announcements which we will proceed to exploit further. Let w_t be the social welfare gained per unit reduction in the variance of the market price on day t from the supply-side certainty price that would prevail at t , $P_{H,t}$. Then the social welfare gain from a government announcement on day $t+1$, W_{t+1} , will be

$$W_{t+1} = w_{t+1}(V_{t+1}^P - \tilde{V}_{t+1}^P) = w_{t+1}\left(\frac{1}{\beta^2}\right)(V_{t+1}^M - \tilde{V}_{t+1}^M) \quad (16)$$

which can be written in terms of the underlying parameters as

$$W_{t+1} = (w_{t+1}/\beta^2) \left(\alpha(2-\alpha) \sum_{t+2}^H \sigma_{M,i}^2 - \alpha^2 \sum_{t+2}^H \sigma_{G,i}^2 \right) \cdot 7/ \quad (17)$$

Since the costs to holding erroneous (ex-post) inventories are greater the longer the inventory is mistakenly held, we assume that the per unit benefit to reducing deviations of P_t around $P_{H,t}$ will be larger the greater is $H-t$, i.e., we assume that $w_{t+1} - w_t < 0$.^{8/}

In general it will be difficult to assign specific values to the w_t 's. As a consequence, it will be difficult to do the type of cost-benefit analysis that is required to determine if government information collection and dissemination is cost effective. We can, however, use (17) for other useful purposes such as suggesting the types of markets in which the returns to government information collection will be the largest.

For example, our model implies that, ceteris paribus, government information will be more valuable the more inelastic the demand for the good is. To see this, we differentiate W_{t+1} with respect to β to obtain

$$\frac{\partial w_{t+1}}{\partial \beta} = \frac{-2(V_{t+1}^M - \tilde{V}_{t+1}^M) \cdot w_{t+1}}{\beta^3} \leq 0 \quad (18)$$

since $\tilde{V}_{t+1}^M \leq V_{t+1}^M$. As β increases, the elasticity of demand for the commodity increases. Thus, as the demand curve flattens, the return from the government's provision of information is reduced. This makes sense since, if the demand curve is perfectly elastic, then there will be no adverse effects on price because of erroneous supply forecasts.

Thus far, we have concentrated on utilizing our framework to derive several intuitive results. While these results are not surprising or unique to this study, they do illustrate that this simple model yields predictions that are consistent with the prevailing economic wisdom. Next, we turn to using the model to derive more subtle results.

IV. Some Theoretical Extensions

In this section, we utilize the theoretical framework outlined above to reveal the circumstances in which government forecasts will be most valuable. We consider factors such as the size of the market, the correlation between government and private information, the volatility of agricultural markets, and the timing and frequency of government forecasts. While we could potentially address other related issues, this list will illustrate the value of the theoretical framework in deriving answers to policy questions concerning the provision of government information.

Market Size, Market Information the Value of Government Information

We can make two points regarding the relationship between the value of government information dissemination to a commodity market and the volume of trade in the market. First, it must be true that the social value of infor-

mation varies directly with the size of the market. Second, the fact that more private information tends to be available in larger markets than in smaller markets does not imply that the government's information collection efforts have a smaller payoff to larger markets. The first point follows from the observation that deviations about the supply-side certainty price will tend to result in larger, and therefore costlier, market-wide inventory errors in larger markets than in smaller markets. Thus the per-unit value of reducing the deviation around the supply-side certainty price, w_t , will be the largest in the largest markets.^{9/}

With regard to our second point, if information is more valuable to a large market, then we would expect to observe more private information collection in larger markets than in smaller markets. However, this does not imply that the government should allocate its resources more heavily to collecting information that would be more relevant to smaller markets. In the first place, as we have shown earlier, so long as the government's information set is not identical to the market's, the government's information will be valuable. Even if the government's announcements supply only a small amount of new information to a large market, the fact that the cost of the absence of that information is spread so heavily may make it more valuable than a lot of new information would be to a much smaller (and otherwise less informed) market.

Government Forecast Error Variance and the Value of Government Information

We now explore how the value of improving government forecasts varies with the government's forecast error variance. As is shown above, as government forecasts improve, the market will rely more heavily on them (i.e., α will increase) and the market's revised-forecast error variance

(\tilde{V}^M) will fall. As the market's forecasts improve, the welfare loss due to forecast errors will drop. However, the welfare gain from a unit reduction in the government's forecast error will depend nonlinearly on the existing level of forecast error variance.

To formalize this argument, notice from (16) that the welfare gain from a government announcement on day t varies inversely with \tilde{V}_t^M . \tilde{V}_t^M in turn, depends upon the variance of the government's forecast errors through (7) and (8). For simplicity assume that the ϵ_i^M 's and ϵ_i^G 's are drawn from stationary distributions so that $\sigma_{M,i}^2 = \sigma_M^2$ and $\sigma_{G,i}^2 = \sigma_G^2$ for $i = 0, 1, \dots, H$. Then the value of α depends upon σ_G^2 according to

$$\alpha = (H - t - 1) \frac{\sigma_M^2}{\sigma_G^2 + \sigma_M^2} \quad (19)$$

and the corresponding value of \tilde{V}_t^M is given by

$$\tilde{V}_t^M = (1 - \alpha)^2 (H - t - 1) \sigma_M^2 + \alpha^2 (H - t - 1) \sigma_G^2. \quad (20)$$

From (19) and (20) it follows that

$$\frac{\partial \tilde{V}_t^M}{\partial \sigma_G^2} = 2(H - t - 1) \frac{\sigma_M^4 \sigma_G}{(\sigma_M^2 + \sigma_G^2)^2} > 0 \quad (21)$$

and

$$\frac{\partial^2 \tilde{V}_t^M}{(\partial \sigma_G^2)^2} = \frac{2\sigma_M^4 (\sigma_M^2 - 3\sigma_G^2)}{(\sigma_M^2 + \sigma_G^2)^3} (H - t - 1). \quad (22)$$

(21) confirms our previous conjecture that improvements in government forecasts must reduce the market's forecast errors monotonically. However, the second derivative indicates that the relationship between the market's fore-

cast error variance and the variance of the government's forecast revision has a sigmoid shape as illustrated in Figure 1. In particular, for a given value of σ_M , \tilde{V}_t^M rises at an increasing rate as σ_G increases until σ_G equals $\sigma_M/\sqrt{3}$. Thereafter, \tilde{V}_t^M rises at a decreasing rate. The limit of \tilde{V}_t^M as σ_G approaches infinity is V_t^M , the market's forecast error variance in the absence of any government information collection. The implication is that at very high or very low values of σ_G , there is little gain to marginal improvements in government forecasts.^{10/}

Volatile Markets and the Value of Government Information

Since the volatility of commodity prices is tied directly to market forecast error variances [according to (13)], we can characterize a volatile commodity market as one which has high values of $\sigma_{M,0}^2, \dots, \sigma_{M,H}^2$ or, maintaining the stationarity assumption made in the previous section, a high value of σ_M^2 . Thus, we can consider within our framework how the market's reliance on government announcements varies with the market's volatility. Formally, we want to deduce the relationship between α and σ_M . From (19) we find that

$$\frac{\partial \alpha}{\partial \sigma_M} = (H - t - 1) \frac{2\sigma_G^2}{(\sigma_M^2 + \sigma_G^2)^2} > 0 \quad (23)$$

and, therefore, the more volatile the market the more reliance the market will place on a given government forecast.

Notice also that the partial derivative of $\partial \alpha / \partial \sigma_G$ with respect to σ_M is positive. This leaves open the possibility that noisy government forecasts in unstable period's are valued more highly than more precise government

forecasts are in stable periods. This point is illustrated in Figure 2. If σ_M rises from σ_{M_1} to σ_{M_2} , α will increase for any given value of σ_G , say σ_{G_1} . In fact, α will not fall even if σ_G rises, provided that σ_G does not exceed σ_{G_2} .

The Timing and Frequency of Government Announcements

From (19) it is obvious that as $t-1$ approaches H , α approaches zero. This simply says that as the market's own information set becomes complete, the government's forecast becomes uninformative. This result leads to the suspicion that earlier announcements are more valuable than later announcements. We can confirm this suspicion by using the social welfare formulation outlined above. We can easily establish that the welfare gains from an announcement on day t will tend to be larger than those from an announcement on day $t+1$, even though the later announcement will tend to be the more accurate of the two. Recall that V_t^P is the variance of the price level on day t when there is no government announcement and \tilde{V}_t^P is the variance of that price following a government announcement on that day. The expected welfare gain from a government announcement on day t that incorporates all of the information available to the government at that point, will be W_t which we assumed earlier to be equal to $w_t(V_t^P - \tilde{V}_t^P)$ where w_t is a weight that falls monotonically with t . Rewriting W_t in terms of the variance of the market's harvest forecast errors before and after the announcement, we get

$$W_t = w_t \left(\frac{1}{\beta^2} (V_t^M - \tilde{V}_t^M) \right) \quad (24)$$

where β is the slope of the market demand curve. Then, using (17),

$$W_t - W_{t+1} = \frac{1}{\beta^2} \{ (w_t - w_{t+1})(v_{t+1}^M - \tilde{v}_{t+1}^M) + w_t [\alpha(2-\alpha)\sigma_{M_t}^2 - \alpha^2\sigma_G^2] \}. \quad (25)$$

It is straightforward to show that this difference is positive.^{11/} Thus, the longer the government waits to release information, the shorter the period of time the market will have to capture the benefits of that information and the longer it will bear the costs of the absence of that information. This analysis implies that frequent government forecasts are more valuable than infrequent, late forecasts, even if these late forecasts are more accurate. At one extreme, if the government waits until day H to make its announcement, the market has already determined the actual harvest value S_H and the value of the announcement to the market will be zero. That is, on day H , $S_H^M = S_H$, $V_H^M = 0$, $\tilde{V}_H^M = 0$ and $W_H = 0$. At the other extreme, the government would continuously distribute the information it collects that is relevant to S_H which, if the market can process information as well as the government, amounts to announcing ϵ_i^G on day i for $i = 0, \dots, H-1$. This would clearly be the way to maximize $\sum_{t=0}^H W_t$.

Government Forecasts and the Optimal Extraction of Market Information

Earlier results show unambiguously that lower government forecast variance increases the value of government announcements. We also know that under some circumstances, government duplication of market information collection activities can increase the value of government announcements. There is another way that the government can use market sector information to improve government forecasts. Ironically, this suggestion would be extremely inexpensive to implement. It simply involves using movements in

market prices to estimate changes in market information using well-known signal-extraction methods.

We noted earlier that price movements between day t and day $t+1$, independent of government announcements, take the form $P_{t+1} - P_t = \frac{1}{\beta} \epsilon_{t+1}^M + \frac{1}{\beta} (u_{t+1} - u_t)$. Thus, if we can estimate β , we have $\beta(P_{t+1} - P_t) = -\epsilon_{t+1}^M + (u_{t+1} - u_t)$. It remains to extract the supply information ϵ_{t+1}^M from the right-hand-side, where $(u_{t+1} - u_t)$ is the demand-side shock. If the sequences $\{\epsilon_{t+1}^M\}$ and $\{u_{t+1} - u_t\}$ have constant finite variances σ_ϵ^M and σ_u , then it is straightforward to show that the best linear estimate of ϵ_{t+1}^M conditioned on $(P_{t+1} - P_t)$ is

$$\epsilon_{t+1}^M = \frac{\sigma_\epsilon^M}{(\sigma_\epsilon^M + \sigma_u)} \cdot \beta(P_{t+1} - P_t) \quad (26)$$

Thus, the government could approximate the changes in market information in periods 0 through t and incorporate this information in the government announcement in period $t+1$. If stable estimates of β , σ_ϵ^M and σ_u can be derived, and if σ_u is not infinite, the government forecast variance taking into account estimated market information must be less than the forecast based on government information alone.

Correlated Market and Government Forecast Errors

To this point we have assumed that the government's daily forecast revisions are statistically independent of the market's revisions, i.e., $E[\epsilon_0^M, \dots, \epsilon_H^M]' [\epsilon_0^G, \dots, \epsilon_H^G] = 0$. Such a restriction would be implausible if, for example, the major source of forecast revisions by both groups is weather information. In such a case we would expect the forecast revisions

of the two groups to be contemporaneously (and positively) correlated. It is not hard to extend our framework in this direction as we show in this section of the paper.

As before, we let \hat{V}_t^M denote the market's (harvest) forecast error variance after it has accounted for a government forecast made on day t . Then, if we let ρ_i denote the correlation between ϵ_i^M and ϵ_i^G and rule out intertemporal correlation between the ϵ^M 's and ϵ^G 's we obtain^{12/}

$$\hat{V}_t^M = (\alpha-1)^2 \sum_{t+1}^H \sigma_{M,i}^2 + \alpha^2 \sum_{t+1}^H \sigma_{G,i}^2 - 2\alpha(\alpha-1) \sum_{t+1}^H \rho_i \sigma_{M,i} \sigma_{G,i} \quad (27)$$

which, assuming stationarity, can be written

$$\hat{V}_t^M = (H-t) \{ (\alpha-1)^2 \sigma_M^2 + \alpha^2 \sigma_G^2 - 2\alpha(\alpha-1) \rho \sigma_M \sigma_G \}. \quad (28)$$

To minimize \hat{V}_t^M , the appropriate value of α can be shown to be^{13/}

$$\alpha = \frac{\sigma_M^2 - \rho \sigma_M \sigma_G}{\sigma_M^2 + \sigma_G^2 - 2\rho \sigma_M \sigma_G}. \quad (29)$$

Clearly, if $\rho = 0$, we obtain our previous results. In general, with nonzero correlation, α is no longer constrained to be between zero and one. In fact, α can be negative, and it can exceed one in absolute value. We will comment on the implications of the size of α below.

Allowing for correlation between the market's and government's forecast revisions also enables us to consider the implications of the government directing its resources to collecting information that is concurrently being collected by the market. Formally, this duplication of effort amounts to analyzing the implications of an increase in the value of ρ on \hat{V}_t^M . Depending on how one views this exercise, we can imagine an increase in ρ as

occurring with or without changes in σ_M^2 and σ_G^2 .^{14/} For our present purposes we will analyze the effect on \hat{V}_t^M of an increase in ρ with σ_M^2 and σ_G^2 held fixed. From (28) and (29) it follows that

$$\frac{d\hat{V}_t^M}{d\rho} = -2(H - t)\alpha(\alpha - 1)\sigma_M\sigma_G. \quad (30)$$

This derivative implies that an increase in the correlation between the market's and government's forecast revisions (with their respective variances held fixed) will lower (raise) the market's forecast error variance following a government announcement if and only if $\alpha(\alpha-1)$ is positive (negative).

To understand the intuition behind the case where increasing the duplication of effort can reduce \hat{V}_t^M , notice that $d\hat{V}_t^M/d\rho < 0$ implies that $\alpha < 0$. In order for α to be negative, it follows from (29) that $\sigma_M^2 < \rho\sigma_M\sigma_G$. This means that the covariance between the market's and government's revisions (ϵ^M and ϵ^G , respectively) is positive and greater than the variance of the market's revisions. Since the market's forecast of the harvest size (S_H) following a government forecast on day t is $(1-\alpha)\hat{S}_t^M + \alpha\hat{S}_t^G$ it follows that $\alpha(\hat{S}_t^G - \hat{S}_t^M)$ is the change in the market's forecast in response to \hat{S}_t^G . When α is negative this means that the market will lower (raise) its own forecast when the government's forecast is unexpectedly high (low). This is because the circumstances that generate a negative α , i.e., $\sigma_M^2 < \rho\sigma_M\sigma_G$ with $\rho > 0$, leads the market to use the government's forecast as a signal of the direction of its own forecast error. An unexpectedly high government forecast is interpreted as meaning that the market's original forecast was too high and

consequently the market revises its forecast downward. As ρ increases, this perception by the market is more likely to be correct and its response a proper one. As a result, \tilde{V}_t^M will fall. Notice that this result implies that a rational market may respond to an unexpectedly large government crop forecast by raising the commodity price.

In the case where $\rho = 0$ we showed earlier that a reduction in the variance of the government's forecast revisions unambiguously reduces the market's forecast error variance following a government announcement. That is, $\partial \tilde{V}_t^M / \partial \sigma_G > 0$. If ρ is not restricted to be zero, then we can no longer claim that a decrease in government forecast error variance will always reduce the market's forecast error variance. The general expression for

$$\frac{\partial \tilde{V}_t^M}{\partial \sigma_G} \text{ is } \frac{d \tilde{V}_t^M}{d \sigma_G} = 2\alpha^2 \sigma_G - 2\alpha(\alpha-1)\rho \sigma_M \frac{16}{\dots} \quad (31)$$

The first term is unambiguously positive and the second term is positive when $0 < \alpha < 1$ and $\rho \geq 0$. However, it is theoretically possible to generate cases in which the second term is negative and larger in absolute value than the first. Whether such cases actually exist is a subject for further empirical study.

In summary, our framework can provide valuable information regarding the effects of a government announcement regardless of the covariance between $\{\epsilon_0^M, \dots, \epsilon_H^M\}$ and $\{\epsilon_0^G, \dots, \epsilon_H^G\}$. However, if these two random vectors are not independent of one another, the conclusions that one would draw from our framework will depend upon the restrictions that are imposed on the

covariance matrix. What, if any restrictions are appropriate is by necessity a matter of empirical study of individual markets. Such empirical studies would be a natural extension of our theoretical framework.

IV. Implications for Empirical Studies of Government Forecasts

As we suggested above, using our model for cost-benefit analysis is extremely difficult since w_t is difficult to measure. We can, however, use the results above to guide an empirical study of whether a given government forecast has value. Recall that α will be nonzero if the government forecast reduces market forecast error variance. It is thus clear that a regression of the form (10) can be used to establish if α is nonzero.

Notice that $\sum_{t+2}^H (\epsilon_i^M - \epsilon_i^G)$ represents the unanticipated portion of the government's announcement (or equivalently, the unanticipated revision from previous government forecast). ϵ_{t+1}^M , u_{t+1} and u_t are all error terms with zero mean. We can thus rewrite (10) as

$$\tilde{P}_{t+1} - P_t = -\frac{\alpha}{\beta} G_{t+1}^u + e_{t+1}, \quad E(e_{t+1}) = 0. \quad (32)$$

The estimated coefficient on the unanticipated portion of the announcement, G_t^u , will be insignificant if α is zero (meaning the market ignores the government announcement) or if β approaches infinity (meaning the demand curve is perfectly elastic). Thus, an insignificant coefficient on G_t^u is evidence that a given government announcement has no value.

It is interesting to note that in the previous papers which look at market responses to government crop forecasts, the measure of the unanticipated government announcement is taken to be the entire difference between the current and the previous government announcements, not just the unanti-

cipated update from the previous announcement.^{17/} It is easy to show that use of the entire update will bias the estimate of α toward zero.^{18/}

Equations such as (27) can be applied to different commodity markets at the same time and to the same commodity market at various times in the crop year. A comparison of the estimated values of α across equations should reveal which announcements are most important to the marketplace and which could be curtailed with the smallest market inefficiency.

VI. Summary

In this paper, we have formulated a model which can serve as a useful basis to address a wide range of issues that pertain to the government sector's role as a provider of information to agricultural (and other) futures markets. The model is one in which private agents trade claims on a daily basis to shares of the stock of a good whose size will not become known until some (known) future date. The market's daily clearing price depends upon the trader's predictions about the size of the stock as well as other (unspecified) factors. Occasionally the government releases information it has collected about the likely size of the stock. The market's response to the government's announcement depends upon the extent to which the announcement reveals new information to the market. Thus, while anticipated government announcements are reflected in the market's price levels, only the unanticipated components of such announcements generate price changes. In other words, our theory is consistent with the Efficient Markets Hypothesis.

Among the many conclusions that we can derive from the theory are the following:

1. Unless the government's forecasts of the stock's size are so noisy

that they contain no relevant information, they will tend to drive the market price toward the price that would prevail in the absence of stock uncertainty.

2. Government information is more valuable (from a social point of view) the more inelastic is the commodity demand curve.

3. Because of the widespread returns to the provision of information in large markets, it may be optimal for the government to direct more of its information collection resources toward such markets, even though these markets are likely to already be collecting information on their own.

4. Noisier government forecasts during unstable periods may be more valuable to the market than more accurate forecasts are during more stable periods. Similarly, forecasts early in the year will be more valuable than later forecasts, even if the latter are more accurate.

5. The more often the government releases its forecasts to the market the better, even if less frequent forecasts would mean more accurate forecasts.

6. Movements in the futures market price contain useful information that the government could partially extract to improve its forecasts.

7. If, prior to a government announcement, the market and government forecast revisions are correlated, then the duplication of information collection by the market and the government can be beneficial or harmful to the market. The answer will depend upon the nature of the covariance matrix of the market's and government's forecast errors. In addition, we show that under certain conditions, an unexpectedly high government crop forecast can actually cause the futures market price to rise in response.

We conclude our analysis with suggestions regarding how data on futures

market prices and government announcements can be used to measure the impact of these announcements. As part of this discussion we explain why simply regressing price changes on the (value of the) announcement itself will tend to underestimate the announcement's impact on the market. This is because of the difference in the effects of the anticipated and unanticipated components of the announcement.

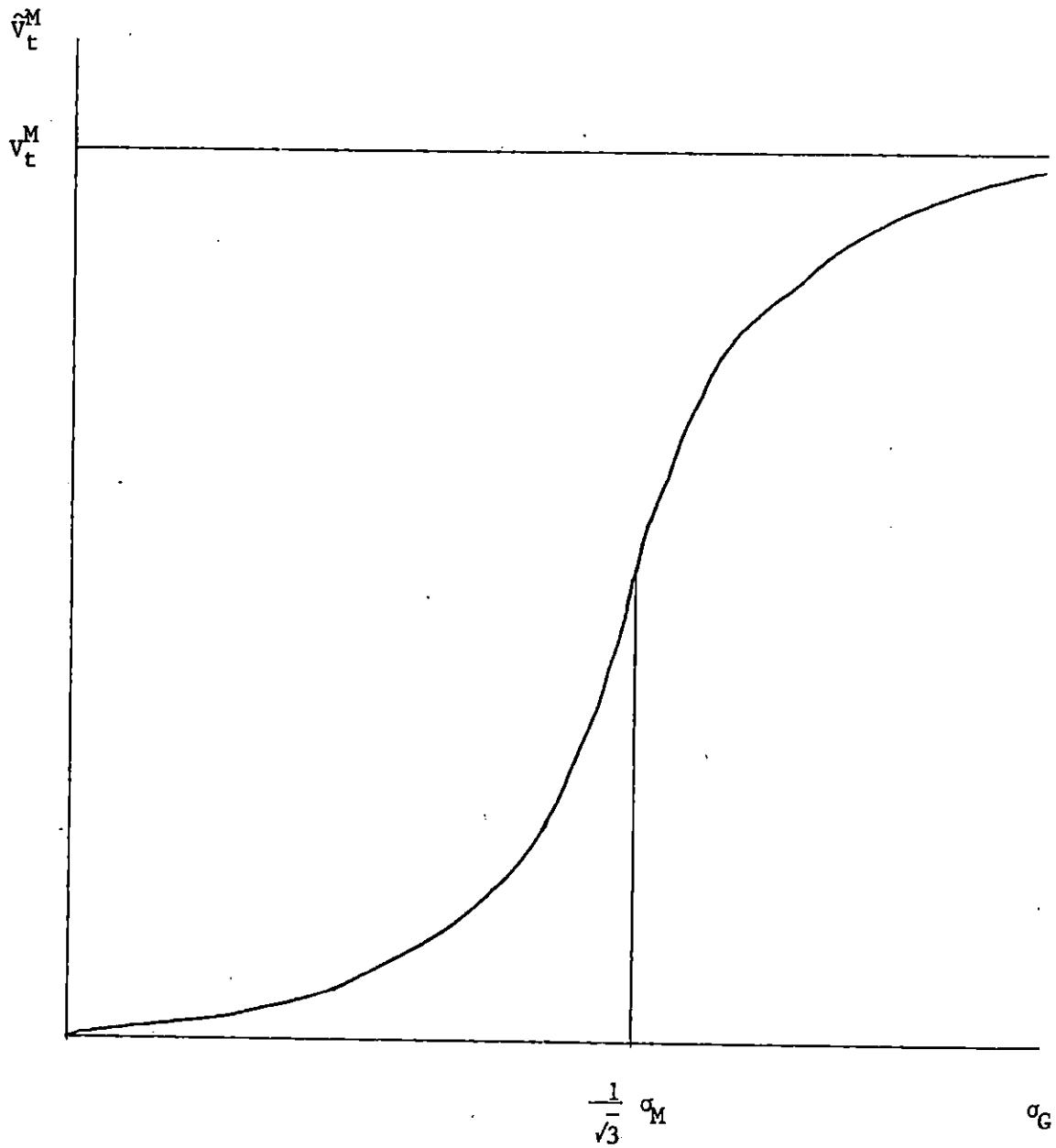


Figure 1: The variance in the market's revised forecast errors given announced government forecasts with standard error σ_G and the market's pre-announcement forecast standard error σ_M .

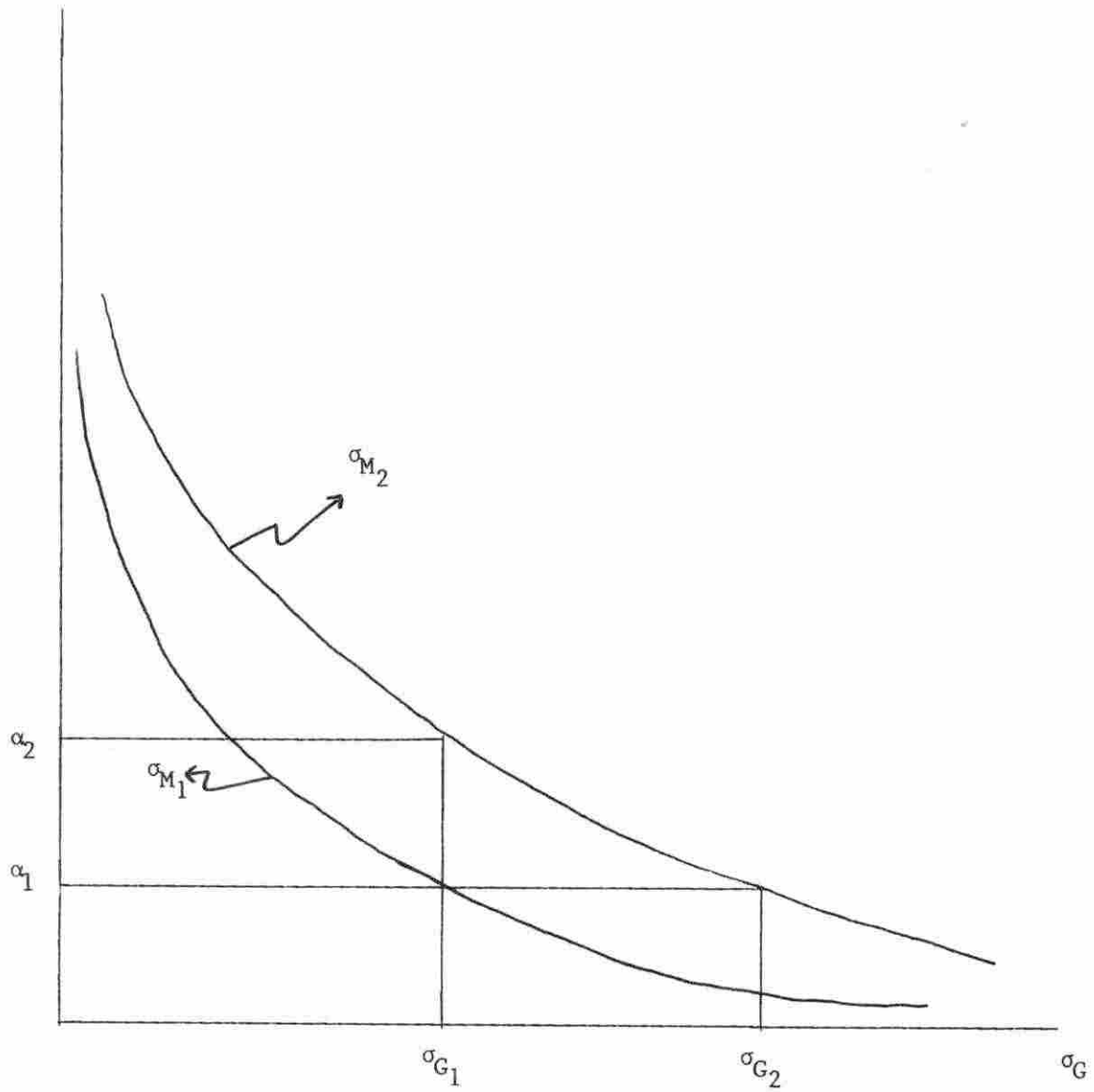


Figure 2: The relationship between the optimal market weight on government forecasts, α , and the standard error of government forecasts, σ_G , given the markets's pre-announcement forecast standard errors σ_{M1} , σ_{M2} , $\sigma_{M1} < \sigma_{M2}$.

Notes

1/ For example, in January, 1983, conflicting crop production and inventory reports were blamed for a period of wildly fluctuating corn and soybean prices. This criticism resurfaced following a large upward adjustment in the USDA estimates of the 1983 soybean harvest was released in September, 1984.

2/ The following analysis is unchanged if we allow a nonzero deterministic component in u_t to account for factors such as basis risk or carrying costs.

3/ The arrival of information to the government and the market will not generally be the same. The market, for example, may have a comparative advantage in obtaining information on current and future inventory plans, food processing plans, and farm input sales. On the otherhand, the government, may have a comparative advantage in collecting and processing information on planting conditions and crop conditions.

4/ Looking at equation (4), it is clear that the government cannot deduce the ϵ^M 's exactly from observed price movements only because of the unobservable demand shocks which also contribute to price movements. At the end of Section III we will return to this issue and suggest a procedure that the government can use to improve their forecasts by estimating the ϵ^M 's from observed price movements.

5/ In Section IV we will consider the implications of relaxing this assumption.

6/ This suggests that, in principle, one can empirically test the joint hypothesis that the market is rational and that government forecasts are

informative since price variations around the true harvest price (P_H) should fall after a government announcement if these hypotheses are true.

7/ This follows from (16) and our earlier results that

$$V_{t+1}^M = \sum_{t+2}^H \sigma_{M,i}^2$$

and

$$\tilde{V}_{t+1}^M = (\alpha-1)^2 \sum_{t+2}^H \sigma_{M,i}^2 + \alpha^2 \sum_{t+2}^H \sigma_{G,i}^2.$$

8/ Inefficient inventory holdings are the source of welfare losses from noisy information in the Hayami, Peterson and Bradford and Kelejian papers as well.

9/ Let N denote the average sales volume in the market. We are assuming the $\partial w_t / \partial N > 0$ and, therefore, $\partial W_t / N > 0$.

10/ This suggests that in empirically assessing the social welfare of a unit reduction in government forecast error variance, one must estimate both the market's and the government's forecast error variances. Because previous studies (e.g., Hayami and Peterson, Bradford and Kelejian (1978)) have assumed that all information is obtained from a public information agency, social returns to more accurate information only involve measures of σ_G^2 . Their theoretical results that unit reduction in the error variance of publicly provided information yield linear or nearly linear increases in social welfare are a consequence of this restriction on the source of information to the market.

11/ Notice, from (16), (17) and our stationarity assumptions, that

$$\alpha(2-\alpha)\sigma_M^2 - \alpha^2\sigma_G^2 = \frac{1}{H-t-1} (V_{t+1}^M - \tilde{V}_{t+1}^M).$$

Thus (25) can be rewritten as

$$w_t - w_{t+1} = \left[\frac{1}{\beta^2} (w_t - w_{t+1}) + \frac{w_t}{H - t - 1} \right] (V_{t+1}^M - \tilde{V}_{t+1}^M).$$

Since we are assuming that $w_t > 0$ and $w_t > w_{t+1}$, it follows that the term in brackets is strictly positive. The difference, $V_{t+1}^M - \tilde{V}_{t+1}^M$, cannot be negative since V_{t+1}^M , the market's forecast error variance in the absence of a government announcement cannot be less than its forecast error variance after it has accounted for the government announcement (\tilde{V}_{t+1}^M).

12/ Equation (27) follows directly from the definition of \tilde{V}_t^M as $E[\{\tilde{S}_t^M - S_H\}^2]$ and equation (6).

13/ This result is found by differentiating \tilde{V}_t^M with respect to α and setting that derivative equal to zero.

14/ In other words, depending on the underlying cause of the increase in ρ , that increase can be accompanied by one of many possible combinations of changes in σ_M^2 and σ_G^2 . If, for example, ρ increases because the market has gained access to data previously available only to the government, we would expect the increase in ρ to occur along with a decrease in σ_M^2 while σ_G^2 remains unchanged.

15/ With σ_G and σ_M being held fixed, (28) and (29) imply that $\tilde{V}_t^M = f(\alpha(\rho), \rho)$. Therefore, $d\tilde{V}_t^M/d\rho = (\partial f/\partial \alpha) \cdot (\partial \alpha/\partial \rho) + \partial f/\partial \rho$. Since $\partial f/\partial \alpha = \partial \tilde{V}_t^M/\partial \alpha$ and α has been constructed so that $\partial \tilde{V}_t^M/\partial \alpha = 0$, it follows that $d\tilde{V}_t^M/d\rho = \partial f/\partial \rho$.

16/ With ρ and σ_M being held fixed, we can proceed to calculate $d\tilde{V}_t^M/d\sigma_G$

in the same manner we used to derive $d\tilde{V}_t^M/d\rho$ (see footnote 15). That is, since by construction $\partial\tilde{V}_t^M/\partial\alpha = 0$, $d\tilde{V}_t^M/d\sigma_G = \partial\tilde{V}_t^M/\partial\sigma_G$ when ρ and α_M are held fixed.

17/ For examples, see Choi (1982), Miller (1979), and Hoffman (1982).

18/ Let G_{t+1}^A be the anticipated revision in the government's forecast so that $G_{t+1}^A + G_{t+1}^U$ equals the total update in the government's forecast from the previous government forecast. The analysis above suggests that G_{t+1}^A will have no effect on price movements on day $t+1$. Thus, if the entire update is used so that $\tilde{P}_{t+1} - P_t$ is regressed on $\frac{\alpha}{\beta}(G_{t+1}^A + G_{t+1}^U)$, we constrain the coefficient on the unanticipated announcement to equal the coefficient on the anticipated announcement, i.e. zero. Thus, using the entire government announcement update in the regression biases the analysis toward rejection of the value of government forecasts.

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